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THE LIFE HISTORY OF THE STRIPED BASS, OR ROCKFISH, *Roccus saxatilis* (WALBAUM)

By John C. Pearson

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THE LIFE HISTORY OF THE STRIPED BASS, OR ROCKFISH, *Roccus saxatilis* (WALBAUM)[1]

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INTRODUCTION

The purpose of this Bulletin is to review a considerable amount of scattered information on the life history of the striped bass, or rockfish, and to present data collected by the author during the course of a study of the spawning habits and migrations of the fish in Chesapeake Bay during 1930–31, and in the Roanoke River, N. C., during May 1937.

The striped bass ranks close to the immortal codfish in the vital part which our fishery resources played in early American history.

In the year 1623 the Plymouth colonists had but one boat left, and that none of the best, which then was the principal support of their lives, for that year it helped them for to improve a net wherewith they took a multitude of bass, which was their livelihood all that summer—Hubbard (1815).

The striped bass astonished the early settlers in New England by its abundance and choice food qualities.

The Basse is an excellent Fish, both fresh and Salte. They are so large, the head of one will give a good eater a dinner, and for daintiness of diet, they excell the Marybones of Beefe. There are such multitudes, that I have seene stopped into the river close adjoining to my house with a sande (seine) at one tide, so many as will loade a ship of 100 tonnes—Morton (1637).

The striped bass and the codfish were probably the first natural resources in colonial America that were subject to conservation measures enacted by statute.

[1] Bulletin No. 28. Approved for publication July 28, 1937.

The following act, passed by the General Court of Massachusetts Bay Colony in 1639, ordered that neither cod nor bass should be used as fertilizer for farm crops:

At the Generall Courte, holden at Boston, the 22nd of the 3rd M., called May, 1639—"And it is forbidden to all men, after the 20th of the next month, to imploy any codd or basse fish for manuring the ground, upon paine that every pson, being a fisherman, that shall sell or imploy any such fish for that end, shall loose the said priviledge of exemption from public charges, & that both fishermen, or others who shall use any of the said fish for that purpose, shall forfeit for every hundred of such fish so imployed for manuring ground twenty shillings & so pportionally for a lesser or greater number; pvided, that it shall bee lawful to use the heads & offal of such fish for corne, this order notwithstanding."

The value and probably the limited supply of striped bass seemed to be realized by the colonists within 19 years after the landing of the Pilgrims at Plymouth.

Another distinction shared by the striped bass was an act of the Plymouth Colony in 1670 that granted all income that should accrue annually to the Colony from the fisheries at Cape Cod for bass, mackerel, or herring, be employed for and toward a free school in some town of this jurisdiction. As a result of this act the first public (free) school of the New World was made possible through moneys derived in part from the sale of striped bass. A portion of this fund was also expended in helping the widows and orphans of men formerly engaged in the service of the Colony.

Appreciation of the striped bass as a superb game fish and a source of unexcelled recreation came during the last century when Herbert (1849) noted that with the sole exception of salmon fishing, striped bass fishing was the finest of the "seaboard varieties of piscatorial sport" and that the striped bass was the "boldest, bravest, strongest, and most active fish that visits the waters of the midland States." Today the striped bass is esteemed far more by sportsmen than by epicures and its value to the Nation is far greater from a recreational than from a food standpoint.

DISTRIBUTION

The striped bass, or rockfish, *Roccus saxatilis* (Walbaum)[2] ranges along the Eastern coast of North America from the St. Lawrence River, Canada, to the Tchefuncta River, La. Introduced on the Pacific coast in San Francisco Bay, in 1879 and 1882, the species now occurs from the Columbia River, Wash., south to Los Angeles County, Calif. The striped bass has probably the most extended geographic range of any American food and game fish. Its ability to exist in fresh, brackish, or salt waters throughout the year and from the cold rivers of Eastern Canada to the subtropical bayous of Louisiana, provides a unique record of successful adaptation to environment. (See fig. 1.)

The most distant inland fresh-water range on the Atlantic coast from which striped bass have been recorded is Quebec, on the St. Lawrence River. Most coastal rivers from New Brunswick to Georgia contained striped bass in abundance in early colonial times according to various writers.[3] Inland coastal ranges for the species have included the Hudson River at Albany, the Delaware River at Lambertville, the Susquehanna River to Luzerne County, Pa., the Potomac River to Great Falls, the Roanoke River at Roanoke Rapids, the Alabama River at Montgomery, and 250 miles up the Sacramento River in California.

Few records exist to define the exact range of the striped bass in tributaries of the Gulf of Mexico. The Escambia River, at Pensacola, Fla., the Alabama River, at

[2] The scientific name of the striped bass has been corrected from *Roccus lineatus* (Bloch) to *Roccus saxatilis* (Walbaum).

[3] Early records of striped bass distribution and abundance are noted by Perley (1850), Atkins (1889), Wood (1634), Mease (1815), Schoepf (1788), and Burns (1886).

Montgomery, Ala., and the Tangipahoe River, at Osyka, Miss., have been recorded as localities where the species has been taken previous to 1884. In recent years additional distributions of the fish have been secured from the Tchefuncta River, La., from the Jordan and Wolf Rivers, Miss., and from various coastal streams along the west coast of Florida, from St. Marks to Pensacola.[4] On the Gulf coast the striped bass appears to be confined to fresh or brackish coastal rivers and is unknown in salt water.

The introduction of the striped bass into California has provided a classic example of successful fish transplantation. From an initial stocking of 435 small fish, brought from New Jersey and liberated in San Francisco Bay in 1879, the species has

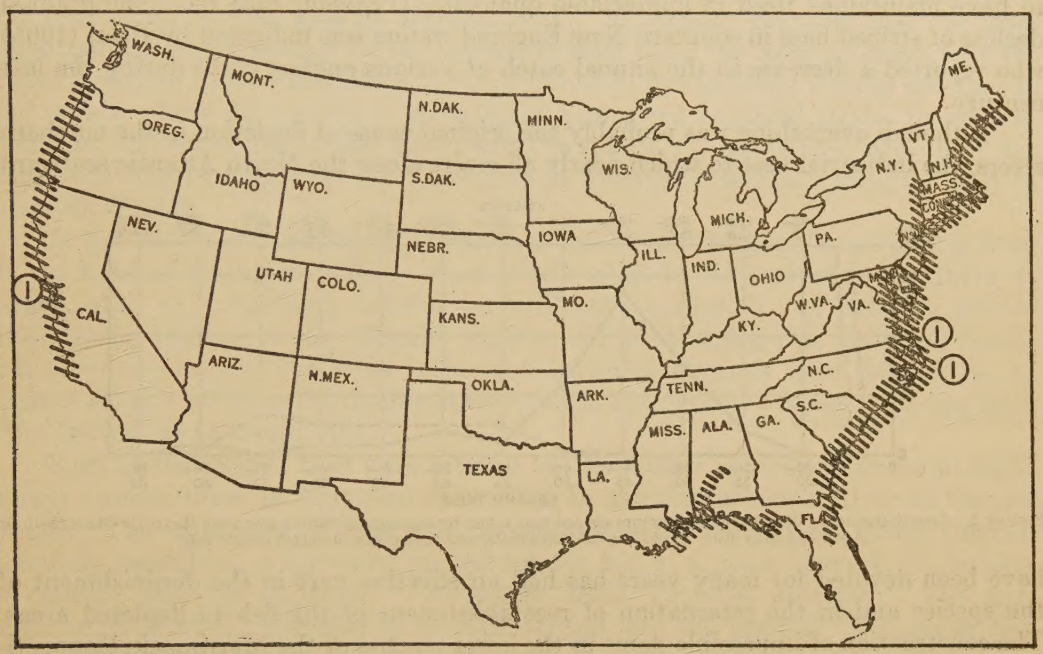

FIGURE 1.—Geographic distribution of striped bass, or rockfish, *Roccus saxatilis* (Walbaum), within the United States. Circle numbers represent centers of commercial abundance.

gradually extended its range to about 850 miles along the Pacific coast. It has become a favorite game fish among many sport fishermen and was reported as a commercial food fish in San Francisco within 10 years after its introduction. The favorite habitat of this species appears to be the fresh and brackish rivers and coastal estuaries. They range freely along the coast line but captures at sea are practically unknown. The record of a 6-pound striped bass, taken on Cod Ledge, 4 miles off Cape Elizabeth, Maine, on October 15, 1931, provides the most distant offshore record.

ABUNDANCE

The notes of early writers indicate that the striped bass formerly occurred in considerable abundance in areas now recognized as completely depleted of this fish. In addition to the striped bass conservation law, enacted in 1639 by the colonists of

[4] The occurrence of considerable numbers of striped bass in various coastal streams of Louisiana, Mississippi, and Florida, has been reliably reported to the author by Whitaker Riggs, of Covington, La., U. A. Cuevas, of Cuevas, Miss., and Robert G. Lincoln, of Minneapolis, Minn.

Massachusetts Bay, New York, in 1758, passed a law to prohibit the sale of bass during the winter months on account of the great decrease of that kind of fish. In 1762 the inhabitants of Marshfield, Mass., also sought to regulate the fishery for bass by passing favorably on a petition to the General Court to enact a bill for the preservation of the fish and to prevent its capture in the winter season.

Abundant as the supply of striped bass may have seemed to many early historians, its ease of capture, because of its large size and habit of dwelling close inshore about coastal streams throughout the year, made possible the depletion of the species over the greater part of its northerly range along the Atlantic coast. North of Cape Cod only one localized population of striped bass, at Parker River, Mass., appears to have maintained itself in appreciable quantities (Pearson, 1933 b). The gradual decline of striped bass in southern New England waters was indicated by Bean (1905) who reported a decrease in the annual catch at various angling clubs during the last century.

Although overfishing was probably the original cause of depletion in the northern rivers, the industrial uses to which nearly all rivers along the North Atlantic seaboard

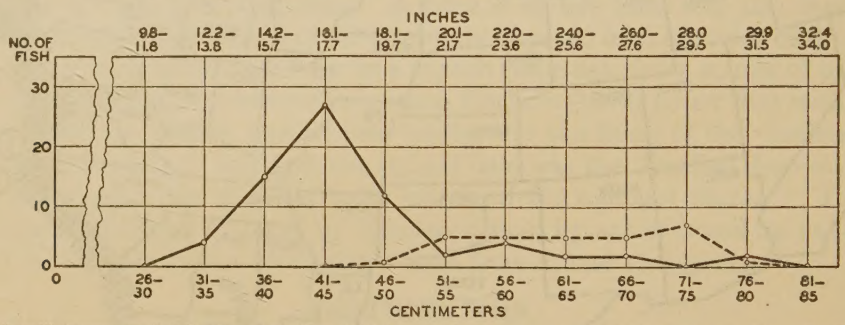

FIGURE 2.—Length-frequency distributions of mature striped bass taken by commercial fishing gear near Havre de Grace, Md., in April and May 1932. Solid line indicates male, and dotted line indicates female fish.

have been devoted for many years has had an effective part in the diminishment of the species and in the retardation of reestablishment of the fish in depleted areas. The construction of impassible dams in the lower reaches of the Merrimack, Connecticut, and Susquehanna Rivers, shutting off probable spawning grounds; the pollution of the Hudson and Delaware Rivers; and unregulated commercial fishing in all sections have been exceedingly detrimental to the striped bass as well as to other anadromous food fishes such as the shad, smelt, salmon, and sturgeon. Restoration of these fishes to their original abundance clearly involves a restoration of coastal streams, where possible, to their primeval conditions of purity and accessibility, together with adequate restrictions against overfishing.

A reduction in the natural supply of striped bass at centers of greatest abundance in Chesapeake Bay and North Carolina has not been so marked as in more northerly areas. This condition has been influenced by the relative absence of industrial development and the limited population in these localities. Nevertheless, a diminishing annual catch of striped bass is noted in many sections of the Southern States. (See fig. 26.)

In California, particularly in the San Francisco Bay region, the striped bass has increased many fold since its introduction. The commercial fishery, prior to 1930, yielded over 17 million pounds despite many years of restricted fishing. In 1931 it became unlawful to take the species by nets and no estimation of their present abundance is possible.

SPAWNING GROUNDS

The first mention of the spawning grounds of the striped bass was probably by Josselyn (1672), who stated: "The Basse is a salt-water fish too but most an end taken in Rivers where they spawn." [5] A more definite spawning habitat was suggested by Schoepf (1788), who, describing the vast number of fishes that came up to the falls on the upper Roanoke River, N. C., every spring, stated that the rockfish (striped bass) especially came up the river in millions to spawn and that being checked at the falls "sprang" and "tumbled" so that the water foamed with the fish.

This spawning area in the Roanoke River, 100 miles above tidewater, was so well defined that it was possible for Holton (1874) to artificially fertilize and hatch the eggs of the striped bass at Weldon, N. C. It appears probable that the most important spawning ground for the species, at least along the Atlantic coast, is in the upper Roanoke River where there occurs a fall of 50 feet in about 6 miles and that in the rapids, where the current is exceedingly strong and rendered erratic by islands, boulders, and rocks, the striped bass prefers to spawn. Collections of eggs from ripe fish for artificial propagation have occurred at irregular intervals during the past 64 years at Weldon.

It has also been noted by observers that ripe striped bass are found during May at the head of Chesapeake Bay. Past efforts made by fish culturists at Havre de Grace, Md., to obtain eggs suitable for artificial fertilization and hatching proved unsuccessful because of the difficulty experienced in obtaining ripe male and female fish simultaneously. The most important spawning grounds were believed to be located along a rocky swift-running stretch of the Susquehanna River extending from Port Deposit to Octoraro, Md.

Eggs of the striped bass were secured by the author in river plankton at night during various times in May and June 1932, in the Susquehanna River at Garrett Island. The occurrence of these eggs, brought down the river by the strong current, definitely establishes a spawning ground for the fish at a point between the locality of capture and the impassable Conowingo Dam, 12 miles upstream. The eggs taken in 1932 would normally have been carried into the head of Chesapeake Bay near the Susquehanna flats.

There occurs only one record of a spawning striped bass from the Gulf coast of the United States. A female with eggs was taken on April 7, 1883, in the Alabama River, near Montgomery.

The deltas of the Sacramento and San Joaquin Rivers are believed to be the principal spawning grounds of the striped bass in California. The fish appear to spawn, according to Scofield (1931), in fresh-water sloughs and creeks. Free eggs have not been taken in California.

The definite records of striped bass eggs in the lower Susquehanna River, and of spawning adults in the upper Roanoke River, indicate that spawning occurs in rock-strewn coastal rivers characterized by rapids and strong currents. Rivers, such as the James, Potomac, and Hudson, offer a similar environment for the spawning fish, and are known to contain either young or ripe adult striped bass.

While some writers have stated that the striped bass spawns in brackish water, there is no conclusive evidence to justify this belief. Ripe striped bass, presumably taken at the entrance to the Hudson River off Governors Island, were noted by Rice (1883). A ripe female fish was caught by Corson (1926) near Barnegat Inlet,

[5] Other early notes on the spawning grounds are in the works of Belknap (1792), Mease (1815), and Mitchell (1815).

N. J. It is well to remember, however, that many anadromous fishes often appear to be near spawning on entering tidal estuaries from the sea but that actual spawning probably does not occur until fresh water is reached.

Many larvae of the striped bass were taken by Leim (1924) during the summers of 1922 and 1923 in the Shubenacadie River, Nova Scotia. The young were taken in plankton near the head of the tidal zone.

SPAWNING SEASON

The spawning season of the striped bass has generally been recognized to occur in the spring and early summer months. Ripe fish have been noted in the rivers of New Brunswick about the middle of June; in Delaware and New York Bays about the middle of May; in the Roanoke River during May; in the Alabama River in April; and in upper San Francisco Bay principally during May.[6]

Ripe fish were taken by Worth (1884 b) at Weldon, N. C., from April 19 to May 17, 1883, at a water temperature rising from 58° to 71° F. This observer also recorded the spawning period at Weldon during 1904, as extending from May 2 to May 24. During hatchery operations at Weldon, in 1931, the first ripe female fish was secured on May 5 and the last on May 21. Water temperatures at the hatchery, supplied by filtered and underground piped city water from the Roanoke River, gradually increased from 61° to 71° F. During hatchery operations at the same point, in 1937, ripe females were taken from about May 7 to May 22.

The eggs of the striped bass were taken in river plankton in the lower Susquehanna River, Md., from May 16 to June 8, 1931. These eggs were secured during the early half of the night and were probably only a few hours spawned. Water temperatures in the river increased from 60° to 70° F. during the period of egg collection.

SIZE AND AGE AT MATURITY

The weights of 19 female striped bass, taken and stripped for eggs at Weldon, N. C., were recorded by Worth (1904). Three females ranged between 3 and 7 pounds, seven from 10 to 18 pounds, four from 23 to 35 pounds, and five from 40 to 70 pounds. The approximate lengths of these ripe fish would have ranged from 20 in. (50.8 cm) to over 4 ft., according to a length-weight correlation given by Scofield (1932).

It appears, on the basis of considerable data collected by Scofield (1931) for California striped bass, that 35 percent of the female fish mature and spawn by their fourth year at an average length of 50 cm (19.7 in.), 87 percent by their fifth year at an average length of 54 cm (21.2 in.), 98 percent by their sixth year at an average length of 61 cm (24 in.), and 100 percent by their seventh year. It was observed that many male striped bass mature and spawn in their third year while all are mature by their fifth year.

Ripe male striped bass, 12–18 in. (30.5–45.7 cm) in length, were taken in the Potomac River, Md., late in April 1875, by Milner (1876).

Length measurements were obtained of 70 mature male and 29 egg-bearing female striped bass taken by commercial fishing gear near the entrance to the Susquehanna River, Chesapeake Bay, during April and May 1932. The lengths of the male fish ranged from 33–78 cm (13–30.7 in.) with an average length of 40–45 cm (15.7–17.7 in.). Most males were approximately 3 years old. The lengths of the female fish

[6] Adams (1873); Mease (1815); Holton (1874); Bean (1884); Smith (1895); and Scofield (1931).

ranged from 50–78 cm (19.7–30.7 in.). No females under 4 years of age were obtained with eggs. The smallest fish taken in these collections probably represent the minimum size of spawning fish in both sexes. The largest fish taken do not represent the maximum size which the species attains because the samples were limited to 15 pounds, about 32 inches in length, by legal-size restrictions. The length-frequency distributions for these striped bass are given in figure 2.

There appears to be many more mature male than female fish on the spawning grounds and the average size of the males is much smaller than that of the females. Both numerical superiority and smaller size of the males may be due to their earlier age at maturity. It was observed by Worth (1903), at Weldon, that where the female fish are in spawning condition the males gather around them in great numbers and there will be 1 large female, weighing from 5–50 pounds, surrounded by 20–50 small males weighing not more than 2 pounds each. A somewhat similar predominance of small males was also noted at Weldon by the writer in May 1937.

EGGS AND YOUNG

The number of eggs spawned by the striped bass was calculated by Worth (1904), who found a total of 14,000 eggs in a 3-pound fish and 3,220,000 eggs in a 50-pound fish. The Manual of Fish Culture (1900) estimated 1,280,000 eggs from a 12-pound striped bass taken in the Susquehanna River in 1897. This estimate is closely approximated by volumetric measurement of the eggs taken from a 13-pound fish, measuring 70 cm (27.5 in.) in length, on May 14, 1932, at Havre de Grace, Md. The count totaled 1,337,000 eggs.

No complete description of the eggs and young of the striped bass has been available, despite frequent artificial propagation of the species. Various writers have offered partial descriptions of the eggs and fry, however, based on fish-cultural operations.[7]

A series of eggs and larvae of the striped bass was obtained during May 1931, at Weldon, N. C., through the artificial fertilization and hatching of the eggs at this point on the Roanoke River by the Bureau of Fisheries and the State of North Carolina. Samples of eggs and larvae were preserved in a weak formalin solution at 12 hour intervals after the fertilization of the eggs. The eggs were stripped from a ripe female at the fishing grounds, fertilized by the usual dry-pan method, and placed in McDonald hatching jars supplied with filtered river water within 30 minutes after fertilization. The eggs were taken and fertilized about 10 p. m. on May 5 and hatched in approximately 48 hours at a water temperature averaging 64.2° F. during the incubation period.

No effort was made to rear the larvae through the introduction of food and consequently all young fish had perished by 312 hours after fertilization of the eggs. Successful attempts were made during May and June 1937, at Weldon and Edenton, N. C., to rear the larval striped bass in aquaria and outdoor ponds through the introduction of natural foods such as *Daphnia*. These rearing experiments provided additional specimens of larval and post-larval fish.[8]

The eggs of the striped bass immediately after fertilization are spherical, nonadhesive, and measure 1.28–1.36 mm in diameter after preservation. The eggs are

[7] These writers include Ferguson and Hughlett (1880), Worth (1882) (1883), Ryder (1885), Scofield and Coleman (1907), Bigelow and Welsh (1924), and Scofield (1931).

[8] The author expresses appreciation to W. C. Bunch for the time and care spent in the preservation of the series of eggs and larvae and Louella E. Cable for the painstaking and accurate drawings contained in this report.

slightly heavier than fresh water and sink to the bottom of unagitated water. However, a slight movement of the water serves to float the eggs and keep them in suspension. The egg membrane, or chorion, appears heavily corrugated and nearly opaque after preservation. Living eggs show a transparent chorion at all times. The yolk sphere is heavily granulated, about 1.10 mm in diameter, of a rather intense green color in live eggs, and usually of a pale amber color in preserved eggs. It contains an amber-colored oil globule that measures 0.56 mm in diameter. Several much smaller oil globules may also be present. (See fig. 3.)

The egg at 15 minutes after fertilization increases by the rapid absorption of water to about 1.84 mm in diameter. The size of the yolk sphere and the oil globule remains the same during the early developmental stages. The blastodisc appears differentiated at one end of the yolk sphere. The chorion, becoming stretched, is less corrugated. It was noted by Scofield and Coleman (1907) that the first cleavage of the germinal disc takes place about 2 hours after fertilization. (See fig. 4.)

The egg at 12 hours after fertilization shows a considerable increase in size. The egg diameter may range from 3.2–3.8 mm and water absorption appears complete. The chorion is thin, transparent, and fragile. The blastoderm is in late cleavage and the periblast appears clearly differentiated about the yolk sphere and becomes a paler green with age. (See fig. 5.)

The egg at 24 hours after fertilization shows no further expansion of the chorion. The embryo becomes differentiated and extends about half way around the circumference of the yolk. A moderately intense pigmentation of the embryo occurs and consists of small black dots distributed over the dorsal aspect of the body and over a part of the adjacent blastoderm. (See fig. 6.)

The egg at 36 hours after fertilization has an embryo about 1.6 mm in length. Eyes become differentiated but lack pigmentation. The posterior part of the embryo body is free from the yolksac. (See fig. 7.)

The egg at 48 hours after fertilization, kept at a temperature averaging 64.2° F., is about to hatch. The embryo is approximately 2.5 mm in length upon leaving the egg. (See fig. 8.)

The larva at 60 hours after fertilization of the egg measures about 3.2 mm in length. The oil globule, embedded in the anterior end of the yolksac, projects beyond the head of the larva. The newly hatched fish tends to settle to the bottom of a still aquarium despite swimming efforts to remain near the surface. A strong current of water, however, enables the fish to keep suspended and in more or less constant motion. Hatchery fish are usually liberated soon after this stage. (See fig. 9.)

The larval fish at 84 hours after fertilization of the egg increases to about 4.4 mm in length. The head projects beyond the oil globule. A series of small chromatophores appears along the ventral surface of the body posterior to the vent but the eyes continue to lack pigmentation. (See fig. 10.)

The larva at 120 hours after fertilization of the egg measures 5.2 mm in length. The eyes now possess pigmentation and the jaws are somewhat developed. The oil globule and yolksac are considerably reduced as the rudiments of the digestive tract appear. The pectoral fins become differentiated. The ventral chromatophores become somewhat stronger and several of them now lie along the edges of the gut. (See fig. 11.)

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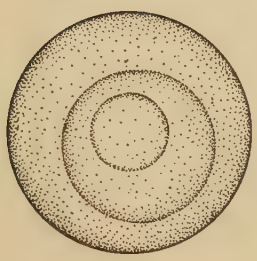

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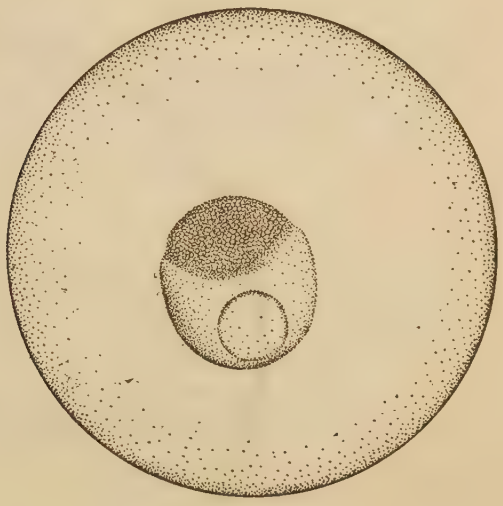

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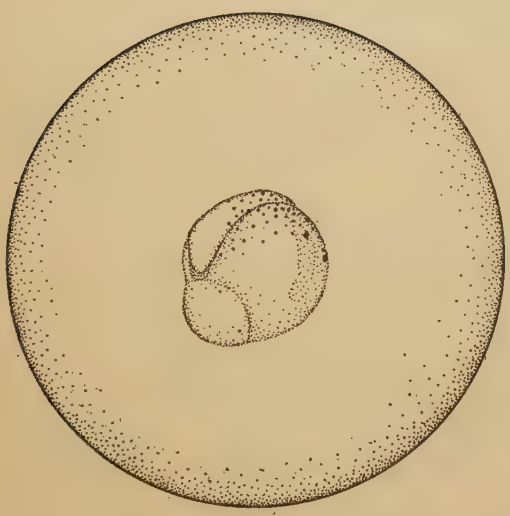

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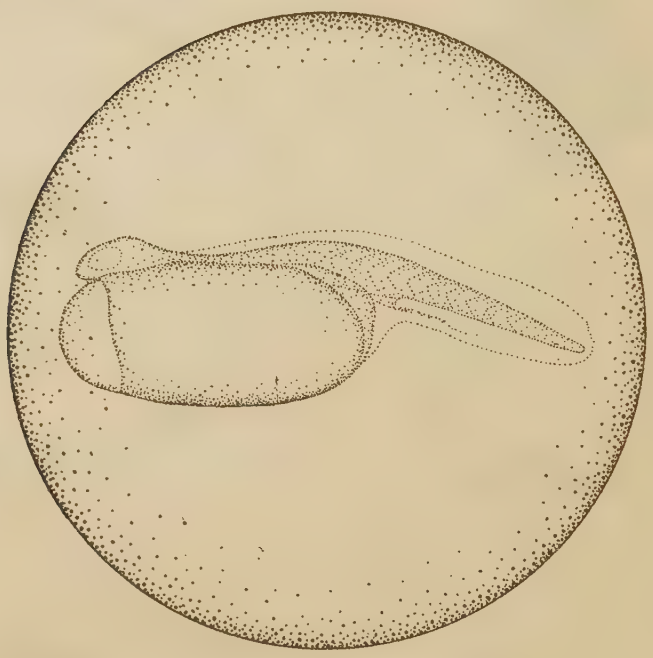
FIGURE 3.—Striped bass egg at fertilization; diameter 1.3 millimeters.

FIGURE 4.—Striped bass egg 15 minutes after fertilization; diameter 1.8 millimeters.

FIGURE 5.—Striped bass egg 12 hours after fertilization; diameter 3.7 millimeters.

FIGURE 6.—Striped bass egg 24 hours after fertilization.

FIGURE 7.—Striped bass egg 36 hours after fertilization.



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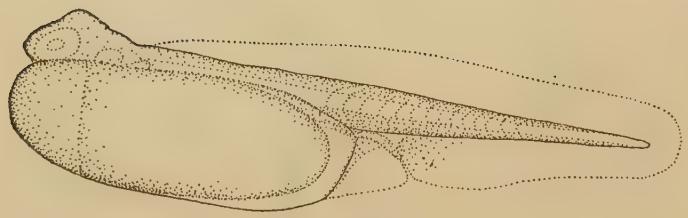

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FIGURE 8.—Striped bass egg 48 hours after fertilization.

FIGURE 9.—Striped bass larva 60 hours after fertilization of egg; length 3.2 millimeters.

FIGURE 10.—Striped bass larva 84 hours after fertilization of egg; length 4.4 millimeters.

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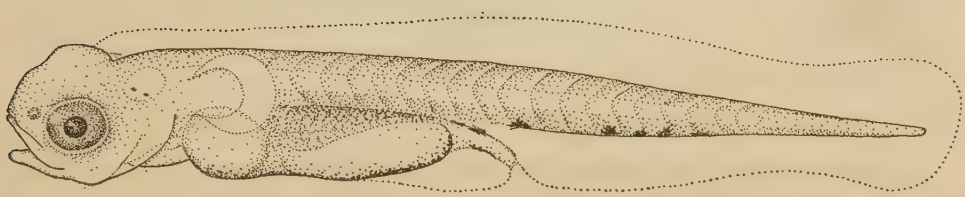

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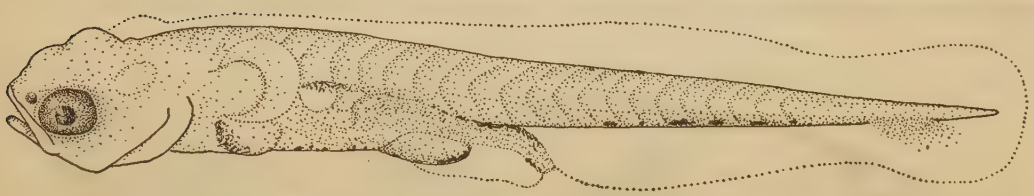

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FIGURE 11.—Striped bass larva 120 hours after fertilization of eggs; length 5.2 millimeters

FIGURE 12.—Striped bass larva 144 hours after fertilization of egg; length 5.8 millimeters.

FIGURE 13.—Striped bass larva 192 hours after fertilization of egg; length 6 millimeters.

FIGURE 14.—Striped bass larva 288 hours after fertilization of egg; length 6 millimeters; no food available to fish.

The larval striped bass at 144 hours after fertilization of the egg reaches about 5.8 mm in length. The mouth parts and digestive tract become better developed preparatory to feeding. A series of small chromatophores now extends along the ventral edge of the entire yolksac. (See fig. 12.)

The larva at 192 hours after fertilization of the egg has the oil globule and yolksac nearly absorbed. The length of the fish increases only slightly, to about 6 mm. Pigmentation on the ventral surface of the body becomes stronger. (See fig. 13.)

FIGURE 15.—Striped bass young 240 hours after fertilization of egg; length 9 millimeters; food available to fish.

The larva at about 288 hours after fertilization of the egg, about 6 mm in length, commences to die rapidly in an aquarium not supplied with food. No fins have developed on the fish except the pectorals. The finfold still extends from the region of the head around the body to the abdomen, becoming interrupted at the vent. A more or less continuous line of pigmentation extends along the ventral portion of the body from the opercle to a point about midway between the vent and the tail. A large chromatophore lies on the upper surface of the swim bladder. (See fig. 14.)

FIGURE 16.—Striped bass young 18 days old; length 13 millimeters; reared in aquarium at Edenton, N. C., May 1937.

The young striped bass reach a post-larval stage at 240 hours after fertilization of the egg provided food is made available. At 9 mm in length the postlarva has lost most of the larval finfold. The second dorsal and anal finrays become slightly differentiated although the first dorsal and ventral fins are wanting. Large chromatophores are scattered profusely on the top of the head and a series of branching chromatophores run along the ventral edge of the body from the head to the tail, becoming interrupted along the intestine and the vent. A regular but broken line of pigmentation extends medially along the side from the pectoral fin to the base of the tail. Mouth parts are well developed. (See fig. 15.)

The postlarva at 13 mm (one-half inch) in length, 18 days after fertilization of the egg, has the dorsal and anal finrays well differentiated. The spinous and soft dorsal fins are still connected by the finfold and the spines are still quite rudimentary. The

body has become much more robust and all traces of the larval finfold are gone. The ventral fins are now present. Pigmentation is heavy and consists of a medial line of chromatophores that extend along the side from the pectoral fin to the tail, a large number of heavy chromatophores on the head, and various scattered markings on the body, expecially in the ventral region. (See fig. 16.)

The young striped bass at a length of 36 mm (1.4 in.) and from 3 to 4 weeks old has the general shape of the adult fish, is well scaled, and has fully developed fins and

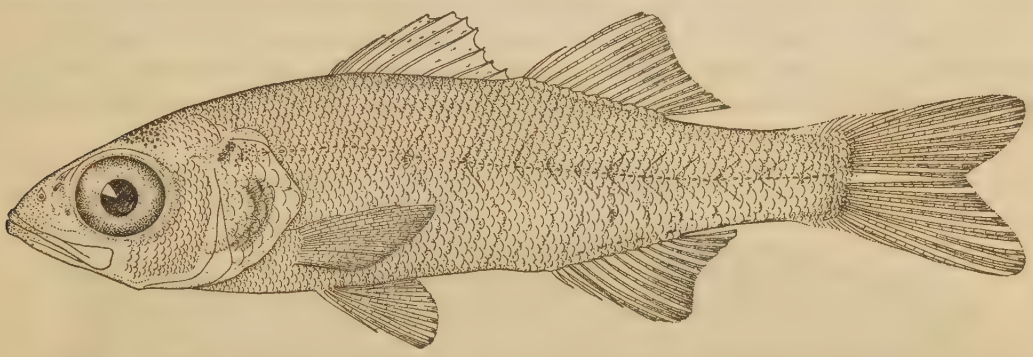

FIGURE 17.—Striped bass young, 36 millimeters (1.4 inches) in length. Taken August 28, 1929, at Back River, Va.

rays. Pigmentation consists of minute black dots scattered over the entire body. Larger chromatophores are present on the top of the head. A series of about nine oblique V-shaped lines appear along the lateral line of the fish and probably represent blood vessels. (See fig. 17.)

The young fish at a length of 130 mm (5.1 in.) and approximately 1 year old possesses the characteristic lateral black stripes ranging from six to eight in number and extending from the edge of the opercle to the base of the tail. There appears also about

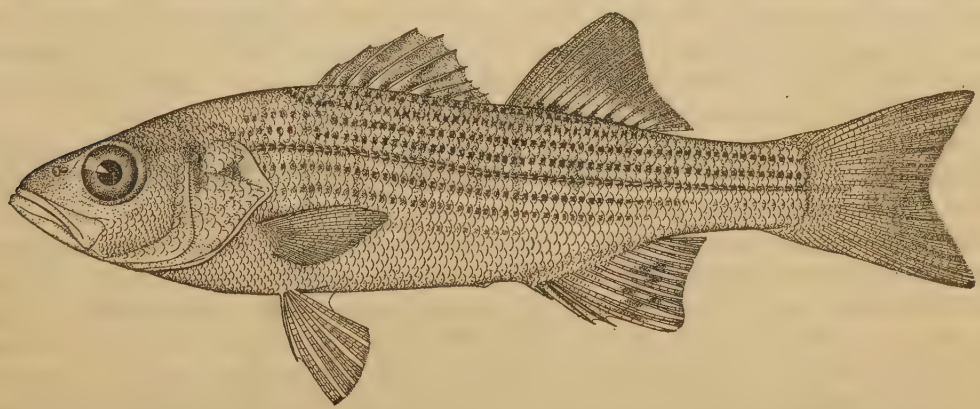

FIGURE 18.—Striped bass young, 130 millimeters (5 inches) in length. Taken June 1, 1932, at Sassafras River, Md.

seven fainter vertical bars extending from the base of the dorsal fins to somewhat below the lateral line. The dorsal and caudal fins are quite heavily marked with fine dots. (See fig. 18.)

GROWTH

A thorough study of the growth of the striped bass in California was made by Scofield (1931). This investigator found that on the basis of length-frequency distributions the average length of the fish at the end of the first year of life (April)

was approximately 10 cm (4 in.), at the end of the second year 25 cm (9.8 in.), at the end of the third year 34 cm (13.4 in.), and at the end of the fourth year about 47 cm (18.5 in.). It was found impossible to determine the age or growth of the species beyond the fourth year by the length-frequency groupings. Calculations of growth for the first 4 years by scale examinations of winter annuli were approximately the same as indicated by the length-frequency distributions. The scales revealed further that at the end of the fifth year the average length of the female striped bass is 54.2 cm (21.3 in.) and of male fish 51.6 cm (20.4 in.), at the end of the sixth year 61.3 cm (24 in.) for female fish and 56.3 cm (22 in.) for males, and at the end of the seventh year 68 cm (26.8 in.) for female fish and 61.2 cm (24 in.) for males. It was noted that both sexes grow at about the same rate during the first year. From then until the fourth

FIGURE 19.—Striped bass adult, 21.4 inches (54.7 centimeters) in length. Taken in April 1880, at Washington, D. C.

year the males are larger, but beyond this point the females continue their rapid growth while the males show a retarded growth. At the end of the tenth year the males are about 7 cm (2.7 in.) shorter than the females. Male striped bass older than 10 years were found to be rare, as were females beyond 16 years.

Various length-frequency distributions of striped bass were secured during the summer months, chiefly in 1931 and 1932, from Chesapeake Bay. Although the number of fish represented are few in most age groups, the annual growth for the first 3 years of life appears approximately the same as for the species resident in California waters. The O age group, or fish in their first year (spawned about May), attain a length of about 4 cm (1.6 in.) by July, and about 9 cm (3.5 in.) by September. The I age group, or 1-year-old fish, attain a length of 20–27 cm (7.9–10.8 in.) with a mode at 25 cm, by August. The II age group, or 2-year-old fish, reach a length of 26–38 cm (10.4–15 in.), with an average length of 31 cm, by July. The III age group, or 3-year-old fish, may reach a length of 34–50 cm (13.5–19.7 in.), with an average length of 40–43 cm by May, or at the approximate third birthday (see fig. 20).

Selectivity of the fishing gear, and the nature of the environment, affected the length-frequency distributions considerably. Likewise, the limited sampling occasioned an unknown error in the determination of the average growth rate. The study of the scales verified the age as indicated by the length-frequency distributions. No attempt was made to determine age or growth after the third year, as material was inadequate.

The early growth of striped bass appears quite rapid, for larvae hatched at Weldon, N. C., on May 14–16, 1937, and planted in a pond at Edenton, N. C., several days after hatching, attained a total length of 30–33 mm (1¼ in.) by June 10, less than a month after hatching.

The maximum growth of the striped bass is indicated by the capture of several fish at Edenton in April 1891, weighing about 125 pounds each. It is of interest to note that Worth (1882) recorded a seine catch of striped bass at Avoca, N. C., on May 6, 1876, composed of 840 fish, totaling over 35,000 pounds. Three hundred and fifty fish are said to have averaged 65 pounds each.

A female striped bass kept on exhibition at the New York Aquarium for over 19 years reached only 20 pounds. It is assumed that this fish did not reach its full

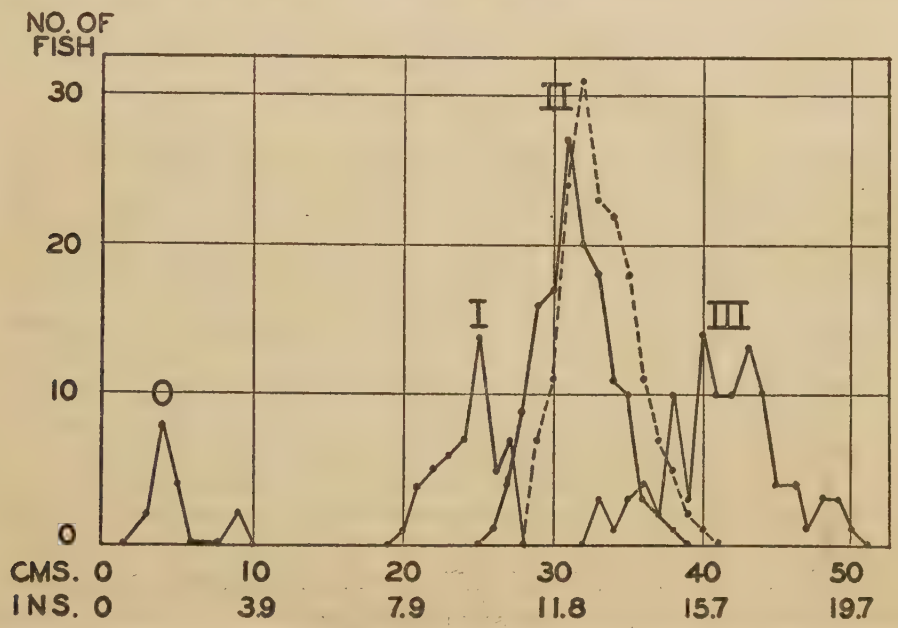

FIGURE 20.—Length-frequency distributions of striped bass taken principally during summers of 1931 and 1932 in Chesapeake Bay. The smaller distribution of O age-group taken in early July; larger distribution in late August. The distribution of I age-group taken during July and August. The smaller distribution of II age-group taken in July; larger distribution in August. The III age-group taken from April to June and composed of mature male fish.

development in captivity where variety of food and freedom of movement were restricted. Length-weight and length-age correlations for California fish (Scofield, 1932) are given in figure 21.

FOOD HABITS

The striped bass is carnivorous, predacious, and an active feeder. The species is known to consume all kinds of fishes and crustaceans. Shad, river herring, and menhaden are favorite prey in fresh and brackish waters, while crabs and lobsters are eaten along rocky coast lines. Shrimps, squids, clams, and other crustaceans have been noted in the stomachs of striped bass taken along the Atlantic seaboard. Young striped bass reared in aquaria were fed live *Daphnia*. Young fish taken in the Hudson River were found to feed largely on the shrimp, *Gammarus* (Curran, 1937).

Investigators on the Pacific coast have found that the species feed on every marine form common to the San Francisco Bay region.[9] The food included the Pacific herring, silver salmon, steelhead trout, shad, carp, and perch; such crustaceans as *Gammarus* and *Neomysis*, and even *Velella*, the Portuguese man-of-war. It has

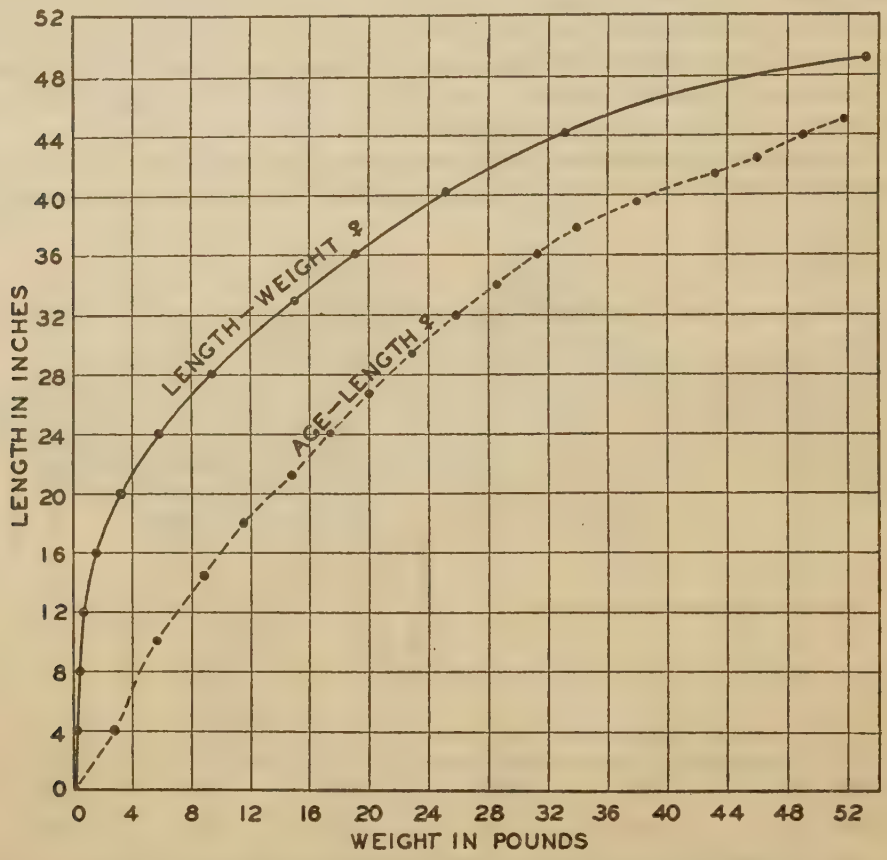

FIGURE 21.—Length-weight and length-age correlation of striped bass in California. After Scofield (1932).

been observed that striped bass feed heaviest in the warm months of the year and in salt water.

Nearly every type of angling bait can be successfully used to hook striped bass. Eel tails, and silvery trolling lures resembling fishes, are particularly effective.

MOVEMENTS

The movements of striped bass can be broadly classed as coastal, seasonal, and spawning. The exact nature and intensity of these movements are probably determined largely by the character of the environment. That coastal movements occur is clearly indicated by the geographic range of the species along the Pacific and Atlantic coasts of the United States. Along the Pacific coast the striped bass has spread from the initial stocking in San Francisco Bay over a coastal range of about 850 miles. Self-sustaining colonies of striped bass are known to exist in San Francisco Bay and

[9] Various writers on the food of striped bass are Ayres (1842), Verrill (1873), Rice (1883), Scofield (1931), Shapovalov (1936), and Merriman (1937).

its tributaries, and in Coos Bay, Oreg., about 400 miles north of San Francisco. Marking experiments in California waters have indicated, however, that no regular or definite coastal movement of striped bass occurs, and that the fish appear to diffuse at random to all points from the locality of release. In a marking experiment in San Francisco Bay, Clark (1936) found that the time elapsing between release and recapture ranged from 4 to 477 days with an average of 111 days of freedom. Yet the distances traveled by the marked fish varied from 0 to 46 miles. Such a restricted dispersion indicates limited coastal movement.

Along the Atlantic seaboard Merriman (1937) has recently shown that seasonal coastal movements of striped bass occur in southern New England with an apparent incursion of fish from southern waters in early summer and a return movement to the south in late fall.

Local seasonal movements of striped bass are quite pronounced. In November and December, as noted by Mease (1815), the fish leave the sea and run into the rivers along the New Jersey coast to pass the winter, where they remain, unless disturbed, until the following spring.

In colonial times a winter fishery for striped bass along the North Atlantic coast was possible because the fish moved into the deep river channels during cold weather and lay semidormant near the bottom, from whence they could be easily captured by large dip nets operated under the river ice. In the tidal Parker River, Mass., the fishery now depends entirely on the formation of firm river ice. It is believed by fishermen that the ebb-tide movement of the river water also tends to force the striped bass off the shallow tidal flats into the deeper channel holes where dip nets can be operated to best advantage. In Chesapeake Bay the striped bass are known to winter in the deeper channels of the bay and river mouths. A concentration of fish is known to occur in a deep channel near Kent Island where fishermen find it profitable to sink gill nets for the sluggish fish. A movement of bass takes place in the fall of the year in California. The fish come out of the bays, run into sloughs, and for some distances up the rivers. When cold weather sets in the fish leave the flats and seek the depths of the channels and sloughs.

In the summer, following spawning, the striped bass leave the rivers and creek and move out into more open areas in the sea or estuaries. This summer movemen of fish appears to be induced by food requirements. As observed by Wood (1634):

> These (striped bass) are at one time when the Alewives passe up the Rivers to be catched in Rivers, in Lobster time at the Rocks, in Macrill time in the Bayes, at Michelmas in the Seas.

In southern waters the species prefers to dwell in fresh or brackish water at all times and relatively few fish are found near ocean inlets or in the open sea. North of Chesapeake Bay a more pronounced movement of bass occurs along the open seacoast during the summer months The annual summer appearance of large striped bass along the sandy beaches of New Jersey and off the rocky headlands of southern New England has provided angling sport for many years.

In California during the summer striped bass from the region of San Francisco Bay move down along the coast of southern California and from upper Suisan Bay down into San Francisco Bay after spawning. These movements, according to Scofield (1931), appear induced by the more abundant food supply in the salt water than in the fresh water of the delta country.

Spawning movements of the species consist essentially of the migration of adult fish from salt, brackish, or fresh waters, up suitable rivers where spawning occurs.

A spawning movement of striped bass was definitely noted in May 1932, at the entrance to the Susquehanna River where captures of ripe fish indicated a nocturnal spawning migration up the river from Chesapeake Bay.

On the upper Roanoke River, at Weldon, N. C., a pronounced spawning movement occurs during the latter part of April and throughout May. This movement provides an opportunity for fishermen to enjoy the sport of capturing the spawning fish with large skim nets. This fishing operation is carried on during the early evening in and just below the rapids.

In the region of San Francisco Bay the spawning migration is made up of fish that come from the deeper holes in the lower rivers and bays, and from the ocean, to run up the Sacramento and San Joaquin Rivers and some of the smaller tributaries. It was thought by Scofield (1931) that a spawning movement of fish also occurred

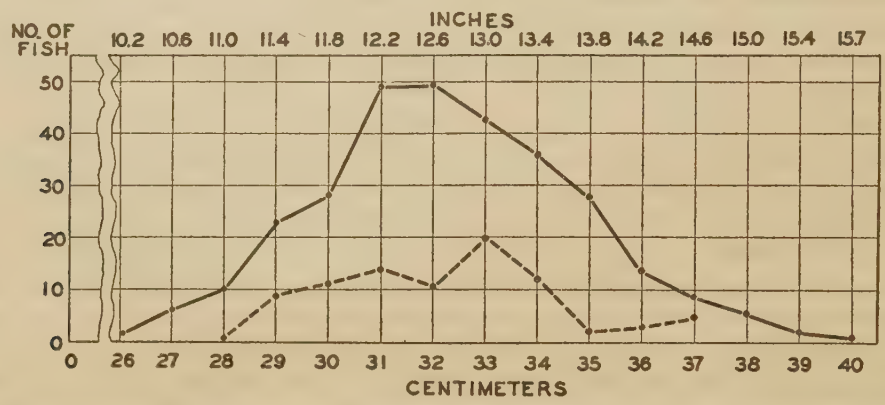

FIGURE 22.—Length-frequency distribution of striped bass marked for migration studies in Chesapeake Bay. Solid line indicates number of fish marked and released; dotted line indicates number of fish recaptured.

from the coast of southern California back to common spawning grounds in the San Francisco Bay area.

An early suggestion of a spawning migration of striped bass involving a parent-stream theory, and the feasibility of stocking depleted streams with fish, was advanced by Belknap in 1792. This historian wrote:

> It is said by some, that fish which are spawned in rivers, and descend to the sea, return to those rivers, only where they are spawned. If this principle be true, the breed might be renewed by bringing some of the bass, which are caught in the Merrimac River, alive, over the land, to the nearest part of the waters of the Piscataqua, a distance of not more than 12 miles. This must be done before the spawning season, and might easily be accomplished.

The first attempt to determine the migrations of the striped bass through marking experiments was made by the author in July and August 1931, in upper Chesapeake Bay (Pearson, 1933 a). A total of 305 fish, ranging in length from 26–40 cm (10.2–15.7 in.) were caught, marked, and released. Most fish were in their third summer (2 years of age) and were immature so far as could be determined. The fish were taken on hook and line and were released immediately at or near the place of capture, about 1 mile east of Hacketts Point, off Annapolis, Md. (See fig. 22.)

The tags were the modified Nesbit disk consisting of two 12-mm (one-half inch) circular celluloid disks connected by a length of nickel wire. The wire, sharpened at one end and headed at the other, was run through one disk and then through the back of the fish slightly below the second dorsal fin and another disk was placed against

the other side of the fish and secured by twisting the end of the wire. One disk was red and bore a serial number to identify the individual fish; the other was white and bore the words: "Bureau of Fisheries, Washington, D. C. Return Both Disks. Reward." A nominal fee was paid for the return of the disks together with information as to date and place of capture.

Soon after marking operations were commenced, on July 7, 1931, disks were returned from various localities in upper Chesapeake Bay and they continued to be returned over a 2-year period. From July 1931, to September 1933, a total of 89 marked fish were recaptured either by sportsmen or commercial fishermen. The

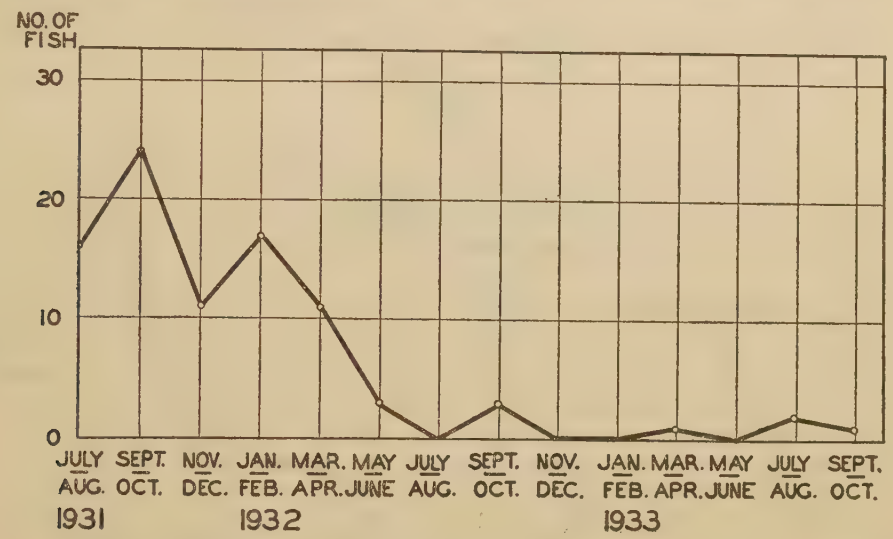

FIGURE 23.—Bimonthly recapture of marked striped bass in upper Chesapeake Bay from July 1931 to September 1933.

recaptured fish totaled 29.1 percent of the number released, or about 1 out of every 3 fish marked. Twenty percent of these fish were retaken within the first 6 months after release. (See fig. 23.)

None of the marked striped bass were recaptured at the immediate point of release. Only 9 fish out of 89 were recaptured south of the point of release off Annapolis, Md. The majority of fish were taken at various points along the shores of upper Chesapeake Bay from the Magothy River and Love Point north to the Susquehanna and Elk Rivers. The point of greatest concentration of marked fish was in the vicinity of Rock Hall near the entrance to the Chester River. (See fig. 24.)

Six out of nine marked fish taken in Chesapeake Bay, or tributaries below the point of release off Annapolis, were recaptured the following spring after marking. One striped bass was recaptured off Maryland Point in the Potomac River on March 17, 1932, while another was secured in the Wicomico River, near Salisbury, on March 23, 1932. These localities were the most distant points to which the marked fish dispersed over a 2-year period.

The steady decrease in the number of recaptured fish after the first 2 months (see fig. 23) was probably caused by the ultimate detachment of the disks from the back of the fish and by the continually reduced number of marked fish available for capture.

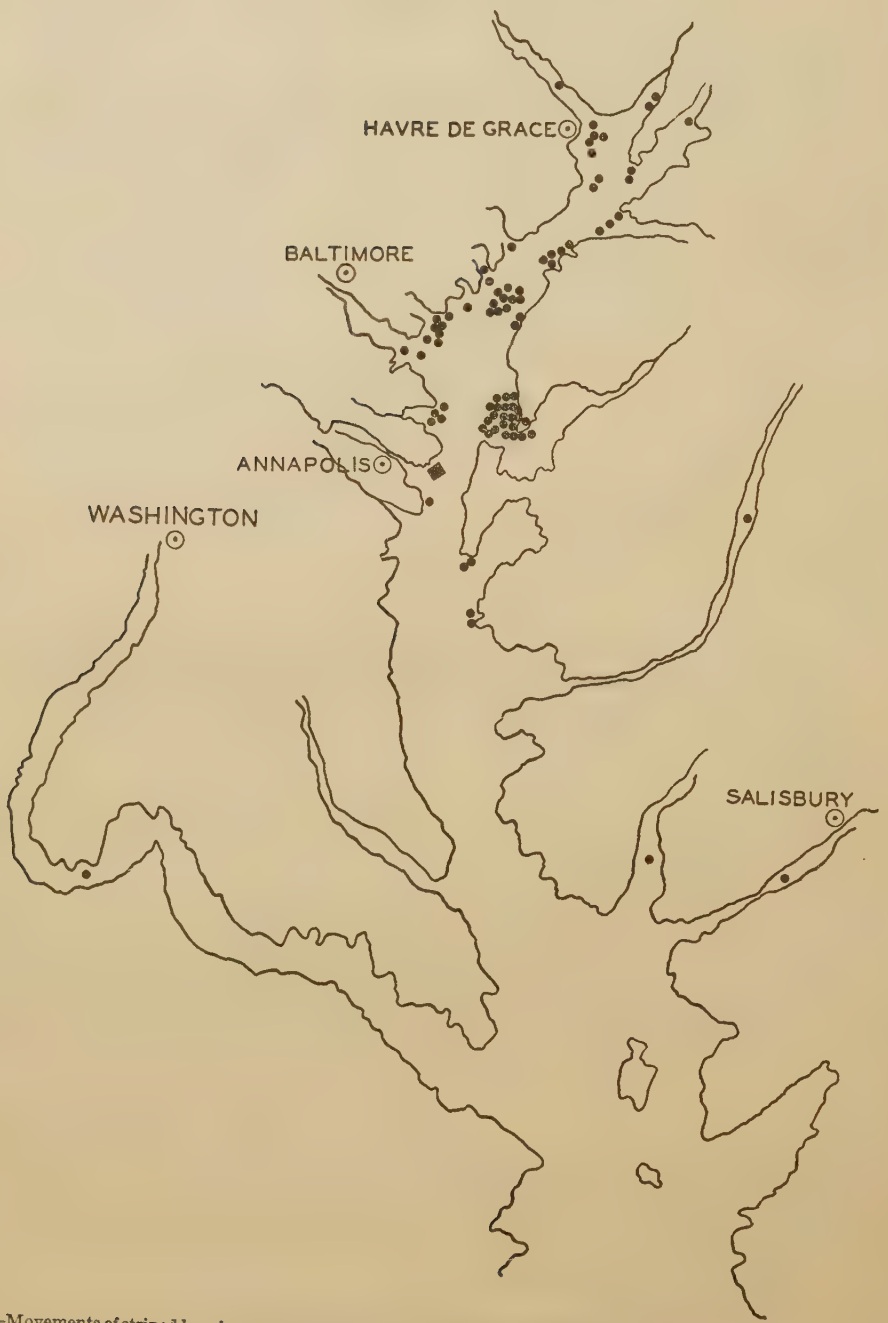

FIGURE 24.—Movements of striped bass in upper Chesapeake Bay, 1931–33. The solid square off Annapolis indicates point of release; dots represent individual recaptures of fish.

It is obvious that a clear-cut movement of fish occurred to the north of the point of release which indicates that the bass preferred the fresh or slightly brackish water at the head of the bay to the more saline water down the bay. South of the point of release the four most distant recaptures were at considerable distances up rivers in brackish water. Although the absence of marked fish south of the Potomac River might indicate a local stock of striped bass in upper Chesapeake Bay, a recent increase in the stock of fish within the entire bay, together with a simultaneous increase in the number of fish annually visiting southern New England waters, suggests that the limited distributions of the marked fish during 1931–33 were perhaps caused by a low population density of striped bass in the upper bay and by an abundance of food for the fish with little incentive for widespread movements in or out of the bay.

FISHERY

The fishery methods employed to capture the striped bass afford ample evidence of the severity of the struggle that this food and game fish has undergone in order to survive. These methods are applicable in most instances to other anadromous fishes, such as the shad and salmon, which have suffered alarming decreases in abundance along our Atlantic coast.

The early settlers in New England laid efficient traps for the striped bass during the summer months as they used to "tide it in and out to the Rivers and Creekes by stretching long seins and weirs across coastal streams at high tide." As the water ebbed from the creeks the stranded fish were often obtained in far greater quantities than the fishermen could haul to land. The fish were consumed either fresh, salted, pickled, or smoked. Pickled bass furnished a medium of trade in the West Indies along with salted codfish. The earliest colonial records of the smoking of striped bass as a means of preservation contain the following statement of Wood (1634):

> They drie them to keepe for Winter, erecting scaffolds in the hot sunshine, making fires likewise underneath them, by whose smoake the flies are expelled till the substance remaine hard and drie. In this manner they dry Basse and other fishes without salt, cutting them very thin to dry suddenly, before the flies spoyle them, or the raine moist them having speciall care to hang them in their smoaky houses, in the night or dankish weather.

In the St. Johns River, New Brunswick, according to Adams (1873), the Indians captured the bass at spawning time. A few canoes would drop down the river, each with an Indian in the bow, spear in hand, and another in the stern paddling gently. A sudden spash close by would indicate a bass and like an arrow the birchbark skiff was shot toward the spot while the man in front, resting on his knees, with much force and dexterity sent his three-pronged harpoon into the fish.

The winter months proved the most destructive to the striped bass in northern waters. The fish normally sought the shelter of river channels during cold weather, lying more or less dormant along the bottom until spring. Fishermen soon learned to capture them under the ice by means of large dip nets (Pearson, 1935 b). The havoc of this type of fishery on the resident stock of striped bass was noted by various early writers.[10]

Various methods have been developed to capture the striped bass in southern rivers. It has been the practice for many years on the Roanoke River near Weldon, N. C., to secure the spawning fish in and below the rapids each spring. The adult fish move up the river in late April and May and, if there is sufficient water in the

[10] Tenney (1795), Mease (1815), and Perley (1850).

river, they distribute themselves about the falls where the strong current renders them inaccessible to fishermen. The fish work upstream into numerous channels between various islands lying amid the rapids. During summer low water fishermen at one time prepared traps to capture the fish in these channels by constructing wooden slides at favorable points in the rapids. The fish, forced to descend the rapids through lowered river level, were guided onto the slides and were forced to remain against slats by the pressure of the current and could be easily removed by the fishermen. As many as 300 fish of 30 pounds each have been removed from a slide in a single day. This efficient fishing device has been recently outlawed by the State of North Carolina. (See fig. 25.)

The striped bass congregate at the foot of the rapids at Weldon and are taken in large quantities during the spawning season by skim nets. A skim net consists of a large bow frame of hickory, about 6 feet long and 4 feet wide, to which is hung a linen net about 6 feet deep and 1½-inch square mesh. The bow frame is fastened to a stout wooden pole at least 20 feet long. Two such nets may be fished from a small power boat simultaneously but a man must sit in the stern of the boat and keep it broadside to the river current as it drifts downstream. A fisherman usually stands amidship holding the net in a rigid vertical position against the gunwale with the bow frame lifted a few inches from the river bottom. The touch of a fish against the net signals the fisherman who quickly lifts the net vertically out of the water and deposits the fish in the boat. The catch consists chiefly of ripe fish from which eggs and milt are taken for artificial propagation.

Most commercial fishery methods for the capture of striped bass are confined, through legal restrictions, to more open areas than narrow river channels and rapids. Pound nets, haul seines, and gill nets effectively take the fish from Rhode Island to North Carolina. Salt-water areas provide the most abundant catches in northern waters while brackish and fresh-water estuaries and rivers afford the best fishing from Chesapeake Bay south. Sunken gill nets are used in winter and drift gill nets in summer. Pound nets or trap nets are most advantageous along the open coast line and off river mouths. Haul seines are favored in large estuaries and purse seines, now outlawed, were formerly employed to capture schooling striped bass in Chesapeake Bay. No commercial fishery for the striped bass now exists in California; the species is reserved for hook-and-line sportsmen.

Commercial catch statistics for striped bass from the waters of Maryland, Virginia, North Carolina, and the Middle Atlantic States are given in figure 26. The annual catch records show a decreasing supply of fish despite the more efficient gear employed. The catch in Maryland decreased from a peak of 1,413,000 pounds in 1925 to 314,000 pounds in 1933. The striped bass in various Middle Atlantic States has provided an annual catch of less than 207,000 pounds (40,000 pounds in 1933) since the early part of the present century although this area in 1889 produced over a million pounds of the fish. North Carolina, relatively free from coastal river obstructions and widespread industrial water pollution, shows a decrease in the catch from 1,175,000 pounds in 1902 to 362,000 pounds in 1934. Virginia, however, shows a steady catch at about one-half million pounds annually.

The intensity of the fishery for striped bass in upper Chesapeake Bay may be estimated by the high return of released fish in a marking experiment conducted in 1931. A total of 29 percent of the 305 released fish were recaptured by fishermen within 2 years, and about 20 percent of these fish were retaken within 6 months after

FIGURE 25.—Rockfish slide in a channel of the Roanoke River at Weldon, N. C. The striped bass spawn in these channels characterized by swift currents.

release. The high rate of recapture is indicative of a severe strain on the local stock of fish.

It is surprising to note that after an extended period of lean years the catch of striped bass in Maryland waters increased from 332,000 pounds in 1934 to 928,000 pounds in 1935. This increase of nearly threefold cannot be definitely explained in the absence of field observations but a likely cause for the greater abundance of fish is suggested. In 1932 the use of the purse seine was forbidden in Maryland. This type of net had accounted for about 25 percent of the annual catch for several years prior to 1931. Although the catch remained low from 1932 to 1934, it is significant that the striped bass do not generally attain commercial size until their third summer. Hence, fish which were spawned in 1933 did not appear in the catch until 1935. It might be assumed that enough adult striped bass 3 years old or older were spared by the abolition of the purse-seine fishery in 1932 to aid greatly in spawning production

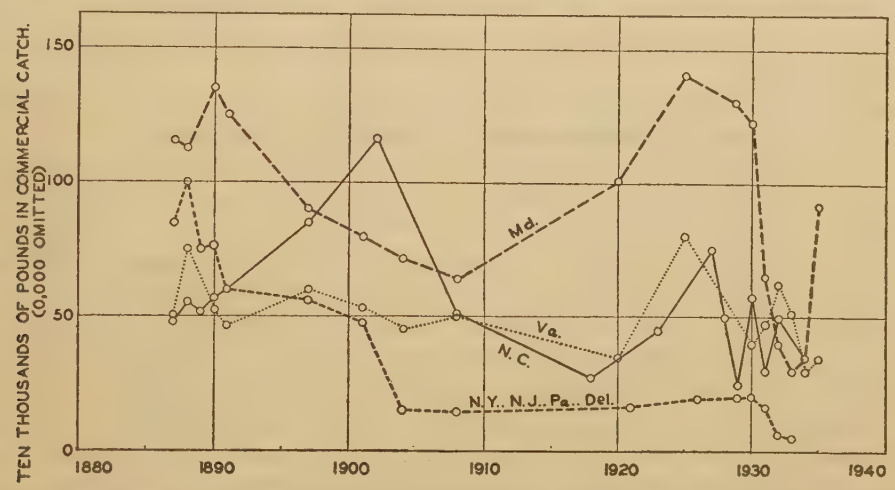

FIGURE 26.—Commercial catch of striped bass in the Middle Atlantic States, Maryland, Virginia, and North Carolina, compiled by Bureau of Fisheries for various years since 1887.

in the spring of 1933. Many fish spawned in 1933 undoubtedly reached the commercial catch during 1935. If such a condition actually occurred then a heavy production of young also occurred in 1934, making possible a large commercial catch in 1936. Field reports again indicate that the striped bass was as abundant in 1936 as in 1935, and that most catches were composed of small fish.

Another indication of the recent increase in the stock of striped bass along the Atlantic seaboard is shown by the incursion of many 2-year-old fish to the coast of southern New England in 1936 as noted by Merriman (1937). This movement of fish into southern New England is perhaps definitely correlated with the increase of striped bass shown by the commercial catch in 1935 in upper Chesapeake Bay. A movement of fish out of Chesapeake Bay and into northern areas may therefore occur at times when the local stock of fish becomes so abundant as to seriously reduce its food supply. Whether depleted northern waters will be permanently restocked as a result of this recent influx of striped bass from apparently overstocked southern areas is unknown.

The striped bass has shown, by its remarkable reproduction in California and its recent increase in Chesapeake Bay, that it has the ability to establish itself as an important aquatic resource in favorable environments within a short period of time. However, unless the fishery strain on the stock of fish in most eastern waters is eased appreciably by adequately restricted fishing, it is feared that only the past glories of this superb food and game fish will remain for future generations to contemplate. Nevertheless, with vigorous and well-considered conservation measures adopted, the striped bass can be expected to increase to some degree of its former abundance and assure the future of the "boldest, bravest, strongest, and most active fish that occurs the year round in our American coastal waters."

SUMMARY

The striped bass, or rockfish, occurs over an extended coastal range along the Atlantic and Pacific coasts of the United States. This fish is also found in small numbers in streams tributary to the Gulf of Mexico from St. Marks, Fla., to Lake Pontchartrain, La.

The species is taken most abundantly at the present time in the fresh and brackish waters of Chesapeake Bay, Albemarle Sound, and San Francisco Bay.

The spawning grounds are located in coastal rivers, apparently characterized by strong rapids and rock-strewn bottoms, and the spawning season extends from late April to early June in most areas.

Sexual maturity, accompanied by spawning, is attained by most male fish at the end of the third year and at a minimum length of about 10 inches. Female fish mature at the end of the fourth year and at a minimum length of about 19 inches.

The eggs of the striped bass are semibuoyant, spherical, and measure about 1.3 millimeters in diameter at fertilization, increasing to about 3.5 millimeters within 12 hours. The eggs hatch in 48 hours at about 65° and in about 36 hours at 71° F. The yolk is absorbed and the young begin feeding by 240 hours after fertilization of the egg.

The average length of the striped bass is 4 inches at the end of the first year; 10 inches at the end of the second year; 15 inches at the end of the third year; and 18.5 inches at the end of the fourth year.

The food of the species is largely fishes and crustaceans.

The striped bass show coastal, seasonal, and spawning movements. Coastal movements are widespread but are probably regulated by the population density of fish in natural centers of abundance. Seasonal movements consist of a summer movement of fish into more open water with better feeding grounds and a winter movement into deep river channels for a semihibernation period. Spawning migration occurs in the spring of the year when the striped bass move up favorable rivers from the sea or estuarine areas.

A marking experiment in upper Chesapeake Bay in 1931 showed purely local movements within the upper bay over a 2-year period with a 29.1 percent recapture of marked fish.

The fishery for striped bass has shown a general decline over the greater part of its range despite a more intensive fishing effort. Restrictive fishing regulations appear to offer suitable means for increasing the stock of fish appreciably.

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